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GUIDELINES FOR THE DOCTORATE IN SCIENCE EDUCATION, A STATEMENT BY THE ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE.

BY- RUTHERFORD, F. JAMES AND OTHERS
NATIONAL SCIENCE TEACHERS ASSN., WASHINGTON, D.C.

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DOCTORAL PROGRAMS IN SCIENCE EDUCATION SHOULD HAVE ADMISSIONS REQUIREMENTS BASED ON ACADEMIC ABILITY, AGE, MATHEMATICS BACKGROUND, AND TEACHING EXPERIENCE. CANDIDATES SHOULD TAKE COURSE WORK EQUIVALENT TO A MASTER'S DEGREE IN ONE AREA OF SCIENCE AND A MINIMUM OF 1 YEAR OF STUDY, INCLUDING LABORATORY, IN THE OTHER MAJOR AREAS. ONE YEAR OF COLLEGE MATHEMATICS, INCLUDING CALCULUS, AND A YEAR OF STATISTICS, INCLUDING RESEARCH DESIGN AND COVARIANT ANALYSIS, SHOULD BE REQUIRED. CANDIDATES SHOULD BECOME FAMILIAR WITH PAST ADVANCES AND CURRENT DEVELOPMENTS IN SCIENCE EDUCATION. SEMINARS OR COURSE WORK SHOULD ALSO BE DEVOTED TO THE HISTORY AND PHILOSOPHY OF SCIENCE AND THE PSYCHOLOGICAL, SOCIOLOGICAL, AND PHILOSOPHICAL FOUNDATIONS OF EDUCATION. CANDIDATES SHOULD BE INVOLVED IN PROFESSIONAL ACTIVITIES AND EDUCATIONAL RESEARCH DURING A MINIMUM RESIDENCE REQUIREMENT OF 1 YEAR. THE DISSERTATION SHOULD DEMONSTRATE THE CANDIDATE'S ABILITY TO DO INDEPENDENT STUDY AND SHOULD BE REPORTED AT A CONFERENCE OR PUBLISHED. THIS ARTICLE IS PUBLISHED IN "THE SCIENCE TEACHER," VOLUME 33, NUMBER 7, OCTOBER 1966. (AG)

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Articles by John A. Moore and Harold H. Punke deal with many aspects of evolution, suggested on the cover by the evolutionary tree of Darwin's finches. Photo courtesy the American Museum of Natural History.

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Guidelines for the Doctorate in Science Education

A statement by the Association for the Education of Teachers in Science[1]

Preface

The report which follows can, in my view, be of the greatest significance in improving the quality of science teaching in the United States. I say "can" rather than "is" simply because all depends upon the spirit with which it is received by those involved in the preparation of doctoral candidates in science education. Programs leading to such doctorates vary distressingly among the various institutions in this country. They vary in requirements for admission, in the type and quality of work required for the degree, and, perhaps most important of all, in the amount of involvement the advanced degree candidate has in on-going research, curriculum development work, and other supervised clinical experience closely related to the kinds of position for which the student is presumed to become prepared.

I do not argue, nor does the report, for lack of variation. I do suggest that the best of our institutions granting doctoral degrees can and should improve their programs and that there are places now offering the doctorate in science education that are *seriously* defective in one or more basic particulars such as admission standards (particularly in respect to the amount and quality of science course work required), in the provision of clinical experiences including that of research and creative work, and—to be quite blunt about it—in the quality of graduate instruction in science education itself.

The report below should not and cannot be a mandate. It can and should be a guide. The standards suggested are often minimal but they make very good sense. I was president of AETS when the "blue ribbon" committee which developed the report was appointed. I know that it did not take its work lightly. Furthermore it worked through, rather than on, the fraternity of science educationists in the country in the production of this report.

Before any science educationist quibbles about any particular provision let him give long and careful thought to the improvement of the profession. Let him seriously give thought to whether his reluctance to accept that provision is because the provision is inadequate or unnecessary or because practical considerations or perhaps plain inertia have prevented the adoption of the standard at his own institution. I am deadly serious about this. It is so very easy to continue doing what we have been doing and to rationalize. Some institutions will require many years to come up to the standards proposed in this report.

But let us be at it. No report is perfect. If, after careful analysis, you believe a standard to be defective, find us a superior one as a replacement. If, on the other hand, you find that the shoe is simply pinching your own institutional toes, be at the internal corrections implied. My shoes are pinching a bit, but I can find little rational argument with the guidelines. Maybe I had better see a chiropodist. Surely there could be nothing wrong with our program. Or could there?

R. Will Burnett
University of Illinois
President of AETS, 1963-64

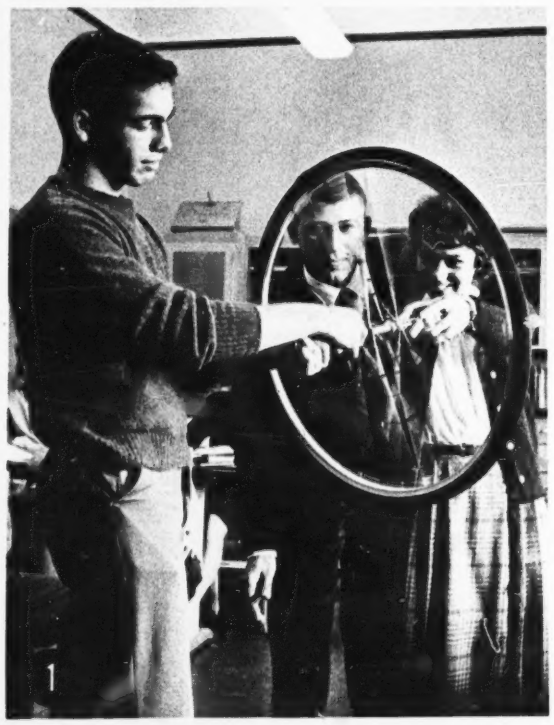
THE need for strong leadership in all aspects of science instruction has been accentuated by the large-scale secondary school curriculum projects, the growth of support for science programs in the schools under the National Defense Education Act, and the recent activity in science curriculum improvement at the elementary school and college levels. Leadership has come from scientists in academic departments as well as from science educators in colleges and universities and at other educational levels. Nevertheless, the only long-term sources of persons trained to provide continuing leadership in precollege science instruction are doctoral programs in science education. Many universities are now in the process of modifying their doctoral programs in science education or of establishing new ones. The task of designing suitable doctoral programs in science education has been hampered by the absence of accepted guidelines. In fact, largely because of this lack of guidelines, there is wide variation in content and quality among programs leading to the doctorate in science education.

The Association for the Education of Teachers in Science (AETS), a section of the National Science Teachers Association, is committed to the improvement of science curricula and of programs for teacher education. Consequently, it is directly concerned with standards for doctoral study in science education. In March 1964 the president of AETS, acting in accordance with recommendations of the executive board, appointed a committee to identify the essential common elements of doctoral programs in science education. The resulting committee report was presented to the membership at the annual meeting in March 1965. A modified report was then circulated widely to persons directly concerned with science education, and their criticisms were sought. The committee has considered all responses carefully in preparing this final document.

The program outlined below represents the thoughtful and informed response of this committee to the charge given it. Nevertheless, the report should be clearly understood to be *not a mandate but a guide*. The intent was to provide (1) a standard which universities could use to evaluate their existing programs in order to decide what changes, if any, should be made, and (2) a model which universities could refer to when trying to decide whether or not to institute a doctoral program in science education, and which, in

[1] Members of the Association for the Education of Teachers in Science present at the annual business meeting held April 1, 1966, authorized the publication and dissemination of the report of the Committee on Guidelines for the Doctorate in Science Education.

On April 19, the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science, recognizing the need for competency in both science and pedagogy, endorsed in principle the AETS committee report "Guidelines for the Doctorate in Science Education" dated April 1, 1966.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the affirmative case, could be used as a guide to the design of the program. Many institutions may wish to initiate or sustain a program which demands more of the candidate; however, it is doubtful that any institution should long permit itself to have standards lower than those suggested here.

The report is divided into four sections: The first discusses the occupational niches for which doctoral programs in science education can be expected to prepare candidates; the second deals with the prerequisites for admission into such programs; the third describes the model program itself; and the final section presents some of the rationale undergirding various features of the program.

The Job of the Science Educator

It is manifestly clear that there are several functions commonly performed by persons designated as "science educators." These may be organized into three categories, each of which delineates (albeit with some overlap) a kind of recognized position. These are:

I. The college or university science educator. This person usually finds himself doing several, and sometimes all, of the following: teaching science methods courses, supervising student teaching in science, directing or supervising and/or teaching inservice training programs for science teachers, participating in local, state, or national science curriculum projects, consulting with schools or school systems on science instruction, analyzing research for its relevance to science instruction, guiding the study of graduate students in science education, and carrying on research.

II. The supervisor, coordinator, or director of science instruction in a school system at local, county, state, or national levels of responsibility. The work usually involves the design and implementation of science programs, the provision of services and materials to facilitate the work of science teachers, and liaison between science teachers and leaders in the schools and persons in other agencies concerned with science instruction. Classroom science teaching at pre-college levels is sometimes involved, as is the teaching of occasional science education courses at nearby universities or extension division centers.

III. The research specialist on programs of science instruction. Like the science educator in Category I, a person in this category is usually located at a university; however, unlike for the teacher or practitioner, the focus of his attention is on, and the bulk of his time and energy is devoted to, research and the guidance of others in research on aspects of science instruction. He may also have some of the duties listed in Category I.

It should be noted that the category "teacher of college-level science" is not among the functions in this list, despite the fact that, at present, some persons trained as science educators devote most or all of their time to the teaching of science rather than to methods of teaching science, to supervised practice, or to research in science education. The committee believes that the proper training for a college science teacher or a research scientist should be quite different from that for a science educator and feels that responsibility for the training program of science professors must reside with scientists and their professional societies. Therefore, the discussion that follows focuses on doctoral programs whose purpose is to prepare teachers, practitioners, and research specialists in science education.

Prerequisites for Admission

General admission standards. Standards for admission to doctoral programs in science education should be not less than those required for admission to the graduate school of arts and sciences at the same institution by whatever measurements are ordinarily used. That is, Graduate Record Examination scores or grade point average or other devices used in making admission decisions throughout the university should also be applied to decisions about those seeking admission to the doctoral program in science education.

Age. For candidates in Categories I and II, the doctorate should normally be completed before age 35, even though time is needed for gaining actual experience in school teaching and for obtaining an up-to-date knowledge of a science before embarking on a doctoral program. In general, candidates for doctorate degrees in science education should be given less and less encouragement to undertake a program if the projected completion date would take them past that age. Those persons who expect to devote their energy to science education research, that is, those in Category III, should be encouraged to complete the degree before the age of 30. The maximum starting age should be adjusted accordingly. This recommendation can be met only if there is a concomitant emphasis on early identification of, and ample financial support for, potential candidates.

Mathematics. Because science is so closely related to and dependent upon mathematics, it is necessary that workers in the field of science education have an adequate background in mathematics. It is recommended that, before beginning a doctoral program, a candidate should have at least one year of college mathematics, preferably calculus.

Classroom experience. Persons entering programs leading to positions of categories I and II should have two to four years of teaching experience in elementary and/or secondary school, but longer classroom experience increases the candidate's age without adding compensating insights. For those going into research one or two years of experience may be sufficient, and not much more than this should be encouraged so that the candidate can complete his doctoral work at an early age.

The Doctoral Program

The following statements indicate the main features of an acceptable program leading to a doctorate in science education. Note that the details and implementation are left to the individual universities.

1. *Depth in science.* By the time he completes the doctoral program in science education, the candidate should also have the equivalent of a contemporary master's degree in an area of science. This means that if he earned a master's degree in an area of science some years earlier, he should, during the period of his doctoral studies, take enough additional graduate courses to bring himself up to date.

2. *Breadth in science.* For Categories I and II the program should ensure that the candidate has at least a one-year course with laboratory in each of the usual school sciences, namely, biology, chemistry, physics, and earth science. While this requirement may in many cases be fulfilled prior to admission to the doctoral program, courses or other means should be used to ensure that the candidate is knowledgeable about modern content and emphasis in these basic areas.

3. *History and/or philosophy of science.* While ideally a full-year course in each of these two subjects might be desired, there are many practical difficulties in fitting them into a program. However, the candidate should be expected to complete no less than a year's study in one or the other of these subjects, a year of study divided between them, or a year's course encompassing both.

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4. *Science education.* By whatever means, the candidate should become well informed about past advances in science education and reach the forefront of curricular and other developments in this field. An advanced course or substantial seminar should be the minimum, but a large number of courses in science education should not be required.

5. *Psychological, sociological, and philosophical foundations of education.* An advanced course or seminar based on each of these disciplines should be expected. The candidate should have an up-to-date knowledge of role orientation, group dynamics, child development, cognitive and personality psychology, and of the school as a social institution.

6. *Statistics.* No less than one full year of study which would carry the student through experimental design and covariant analysis or the equivalent should be required. A knowledge of some computer techniques would be desirable. Category III candidates should be expected to acquire the more advanced statistical skills.

7. *Mathematics.* Candidates should take one year of college mathematics in addition to the year required for admission. This should be calculus unless the candidate has already taken it.

8. *Dissertation.* A dissertation should be required so that the candidate can demonstrate his capability to plan and carry out a significant independent study. While the study should be restricted in scope so that the candidate can complete the dissertation in a reasonable time, it should nevertheless be significant enough and of such quality that it can serve as the basis for a report to the profession. The report will ordinarily take the form of a paper delivered at a conference, a published article, or preferably both.

9. *Professional involvement.* During his period of residency the candidate should be actively engaged in experiences pointing directly toward his career goal. For example, with counsel and criticism of his performance by staff members in science education he might teach portions of a methods course or participate in supervision of science teachers.

10. *Research involvement.* During his residency the candidate should be involved in some aspect of research in science education. This is to be expected especially of those candidates who are not going to be primarily research workers. In order to meet this standard the institution must have adequate research facilities and suitably staffed on-going research activities, including research in science education.

11. *Doctoral committee.* The doctoral committee which supervises the work of a candidate in science education should contain representatives from relevant academic areas (science disciplines, psychology, statistics, etc.) and from education. History and/or philosophy of science are accepted as appropriate disciplines.

12. *Residency.* The program should require at least two years, preferably consecutive, of full-time residency. In some cases one year of residency obtained during a recently completed master's degree program may be included, but in no case should a candidate be permitted to obtain the doctor's degree without spending one academic year in full-time residence on campus.

13. *Time limitation.* The requirements listed above can form a unified and purposeful program of study only if they are completed over a relatively short period of time. For candidates in Categories I and II, the interval from admission to completion of the program should not exceed seven years, while for candidates in Category III the interval should not exceed five years.

Rationale

A complete argument in behalf of each feature of the model program just outlined cannot be given here. However, a brief statement of the assumptions made and the reasoning involved may do since it has been shown elsewhere [2] that the science education profession accepts such a program in principle.

The numbers identifying the following statements refer to the similarly numbered features of the model in the preceding section.

1. The future of science instruction in the elementary and secondary schools will be best served by the continuous and cooperative efforts of science educators and scientists working together on problems of teacher preparation and on science curriculum. It is important, therefore, that science educators have a sufficiently deep knowledge of science based on advanced study in some field of science; similarly, of course, scientists who agree to work in the realm of science education ought to be expected to acquire more than a superficial knowledge of educational theory and practice. Given this considerable overlap in their training, the scientist and the science educator can discuss problems of curriculum and science instruction for the elementary and secondary schools on a basis of mutual respect and support.

2. In addition to having some depth in a single science, a science educator must be competent enough to help science

[2] James Rutherford. "American University Policies and Practice in Preparing Leaders in Science Education—A Research Report." *Journal of Research in Science Teaching* 1:104-116; 1963.

teachers in biology, chemistry, physics, and the earth sciences. He must have at least a minimum competence in these fields. The committee believes that for Categories I and II its recommendation here is an absolute minimum, and a second year of study in each of the fields would be highly desirable.

3. Work in curriculum design requires that science be seen in perspective and understood in both its historical and contemporary aspects. An understanding of the history and philosophy of science is essential to the development of such perspective.

4. A science educator can hardly be competent unless he is aware of the current developments in his field. Science instruction has been radically altered in the past decade by a series of events and developments. Whether he is teaching undergraduates, supervising prospective science teachers, working in the graduate program, or whether he is employed as a science education expert by a local school district, a science educator must be familiar with current curriculum developments and he must understand the philosophy which gave rise to their development. Furthermore, he should be well acquainted with the current research in science education and understand the trends and issues of science instruction.

5. The specialist in science education is also an educator. He must be able to communicate effectively in the field of professional education, as well as in a field of science. Improvement in science instruction, as in all education, calls for an understanding of the sociological and psychological factors involved in learning. The science educator needs to have a suitable mastery of the problems of curriculum development and supervision. He should be competent to a degree which will permit him to make contributions to general educational theory. He should not be insulated from the general problems of education in other academic areas.

6. Every science educator should have command of statistical theory which will permit him to interpret and to evaluate current research. Those in Categories I and III should reach a level sufficient to permit them to direct graduate study and do original research.

7. Mathematics is a basic and fundamental tool of modern science, and it is required to understand much of the research both in science and in education which is being reported in the journals. Calculus is an important tool for work in any area of science as well as in education.

8. The dissertation or its equivalent is still the best vehicle for focusing the work of a doctoral study. However, many of the studies now being completed are not well designed and are often too long and too diffuse. If there is a substantial science education research program at an institution, it should be possible to pattern a series of related research studies which will be suitable as dissertation topics and which will, collectively, result in a unique and substantial contribution to the field of science education.

9 and 10. The need to be directly involved as an apprentice in the kind of work one will ultimately do requires no defense. It is merely a belated recognition in education of a practice in graduate study which has long been accepted in medicine, law, science, and other fields.

11. The work of science educators has both academic and professional dimensions. The individual science educator must serve as a link between scholars in different disciplines as well as between them and teachers. Consequently, it is appropriate for the doctoral committee to be comprised of representatives from the candidate's science area as well as from the field of professional education. Such a provision may help insure that the candidate's science background will be adequate and that his knowledge of science is both sufficient and contemporary. Furthermore, scientists are more likely to cooperate with science educators if they are given some responsibility in their training. Similar arguments hold in addition for psychology, sociology, or whatever other academic field the candidate studies in a major way.

12. Full-time residency is essential if the candidate is to become immersed in his discipline. He must be at a place where he can work with other graduate students in the same field, as well as with academic leaders in his own and related fields, where he can participate in seminars, formal and informal, and in research. Full-time residency is much more likely to insure this kind of experience than work taken sporadically or on a commuter basis.

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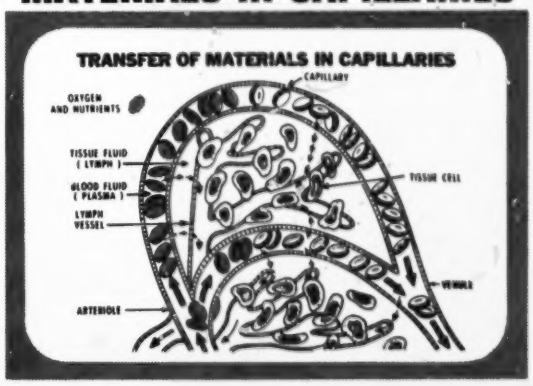

2 Overlay 1 in position

The basic diagram represents a typical capillary loop. The flow of blood plasma, its leakage through the capillary wall, and its return as lymph through lymph vessels is indicated by arrows. **Overlay 1** colors the oxygen-rich corpuscles red and shows the movement of oxygen and nutrients to the tissue cells. **Overlay 2** colors the deoxygenated corpuscles purple and shows carbon dioxide and other wastes leaving the tissue fluid and re-entering the capillary.

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